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SWEATING AND GLYCOGENOLYSIS IN THE PALMAR ECCRINE SWEAT GLANDS OF THE RHESUS MONKEY*

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Sweating may produce depletion of stainable glycogen from the cells of both the duct and the secretory coil of the human eccrine sweat gland (1, 2, 3). A slight decrease in the amount of this glycogen has also been found in the secretory cells of the Japanese monkey (*Macaca fuscata*) (4). In the rhesus monkey, as in man, at least some of the energy used to produce sweat may come from the breakdown of glycogen stored in the clear cells of the secretory coil.

Glycogen is a complex polymer of α-D-glucose joined partly by 1,6 glycosidic linkages, but mainly by 1,4 glycosidic linkages. In glycogenolysis, the enzyme, phosphorylase *a*, splits off glucose units by cleavage of the 1,4 linkages. This enzyme can be demonstrated histochemically by the method of Godlewski (5, 6). In this technic, phosphorylase phosphatase, which converts the active enzyme, phosphorylase *a*, to the inactive, phosphorylase *b*, is inhibited by fluoride. In addition, EDTA (ethylenediamine tetraacetic acid) is used to inhibit phosphorylase kinase which converts phosphorylase *b* to the *a* form. Phosphorylase *b* can be demonstrated by the technic of Takeuchi and Kuriaki (7) by activation of this enzyme with adenosine-5′-phosphate (AMP) in concentrations in excess of those found in normal cells. Thus if both technics are used on serial sections, phosphorylase activity can be differentially evaluated. Unfortunately, the entire process of glycogenolysis cannot be observed histochemically since there is no technic available to demonstrate amylo-1,6-glucosidase activity which is responsible for cleaving terminal 1,6-glycoside linkages.

In this study phosphorylase activity was observed histochemically before and after sweating in the palmar sweat glands of rhesus monkeys (*Macaca mulatta*). This area was selected because of its dense population of sweat glands and because it is in this area that the sweat glands of man and the subhuman primates are probably most similar (3, 8).

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MATERIALS AND METHODS

Nine adult rhesus monkeys, five male and four female, were used. Eight of the animals were anesthetized with 2 mg/kg of phencyclidine (Sernyl, Parke-Davis); the ninth was anesthetized with 3 mg/kg of Sernyl and 0.2 mg atropine sulfate (Lilly). Increased sweating was induced in the digital pads by injection of 40 μgm (60–80 μgm in the pollex) of acetyl-β-methylcholine (Mecholyl, Merck) and 3–6 units of hyaluronidase (Wyeth) dissolved in physiological saline. This injection was repeated every 15 to 20 minutes in the longer experiments. In five of the animals the digital pads used as controls were injected with 4 μgm of atropine; in the other four the controls were untreated. Biopsy specimens were taken 7 to 45 minutes after injection. The tissue for enzyme studies was frozen in liquid nitrogen or a mixture of dry ice and petroleum ether and cut on a Sartorius freezing microtome at 40 μ. The tissue for paraffin sections was fixed for four hours in chilled Helly's fluid, washed overnight in several changes of distilled water, dehydrargyrified one to one and one-half hours in 0.5% iodine, dehydrated in ethanol, cleared in xylene, and infiltrated at atmospheric pressure.

Total phosphorylase was shown by the method of Takeuchi and Kuriaki (7), omitting insulin (5); phosphorylase *a*, by the method of Godlewski (5, 6). Glycogen was demonstrated by the PAS technic as modified by Montagna *et al.* (9). In several cases it was impossible to obtain sufficient tissue to demonstrate both phosphorylase and glycogen in the same animal.

RESULTS

The amount of sweating produced by the injection of mecholyl was variable but was most often copious.

Before sweating, glycogen was plentiful in the secretory coil, especially in the clear cells. Only small amounts were present in the duct. After sweating there was less glycogen in the secretory coil, but in the duct there was no

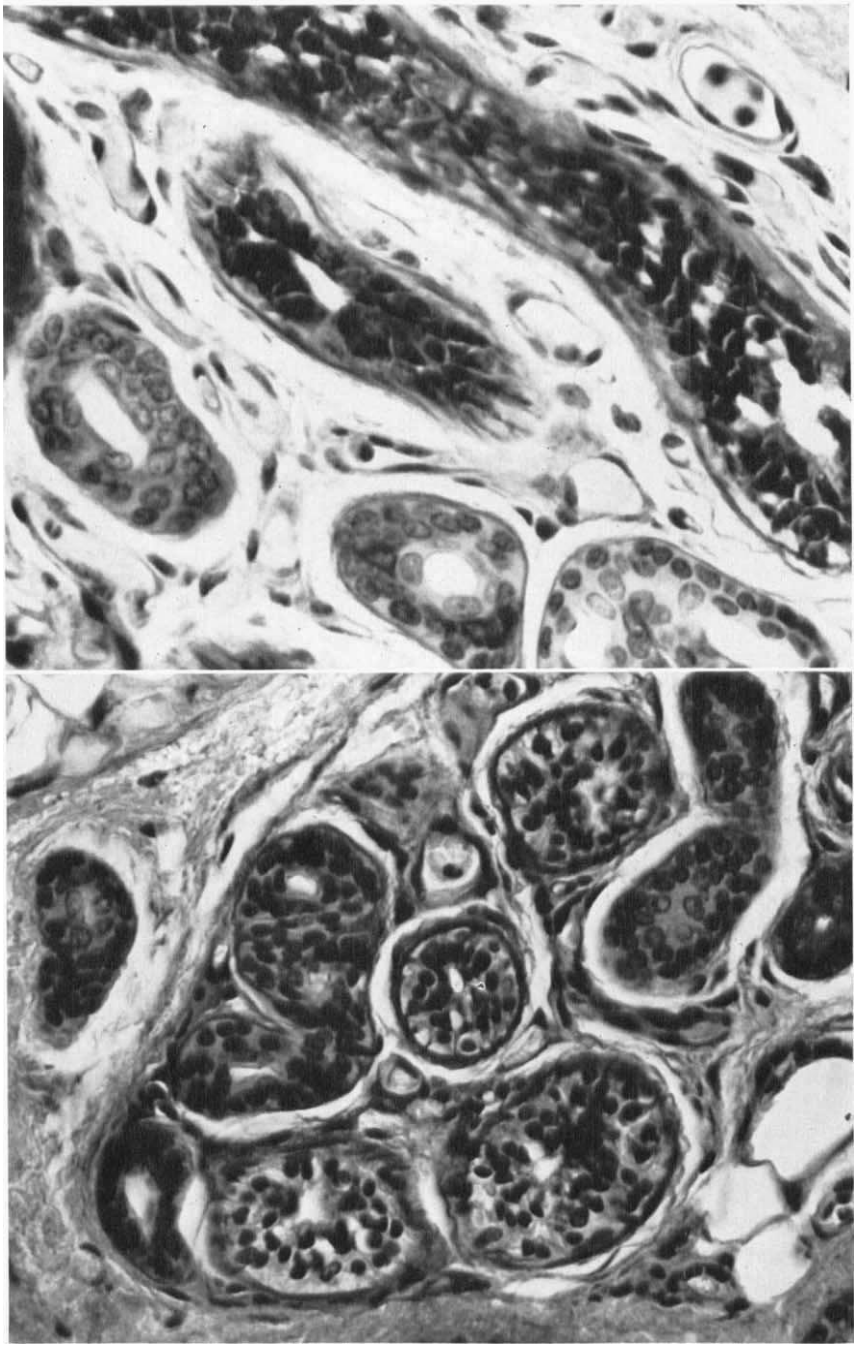

FIG. 1. Sweat gland before sweating. Glycogen is present in the secretory coil (dense nuclei) but not in the coiled duct (clear nuclei). (PAS & hematoxylin—× 640)

FIG. 2. Sweat gland after 45 min. of sweating. Glycogen has disappeared from the secretory coil (PAS & hematoxylin—× 310).

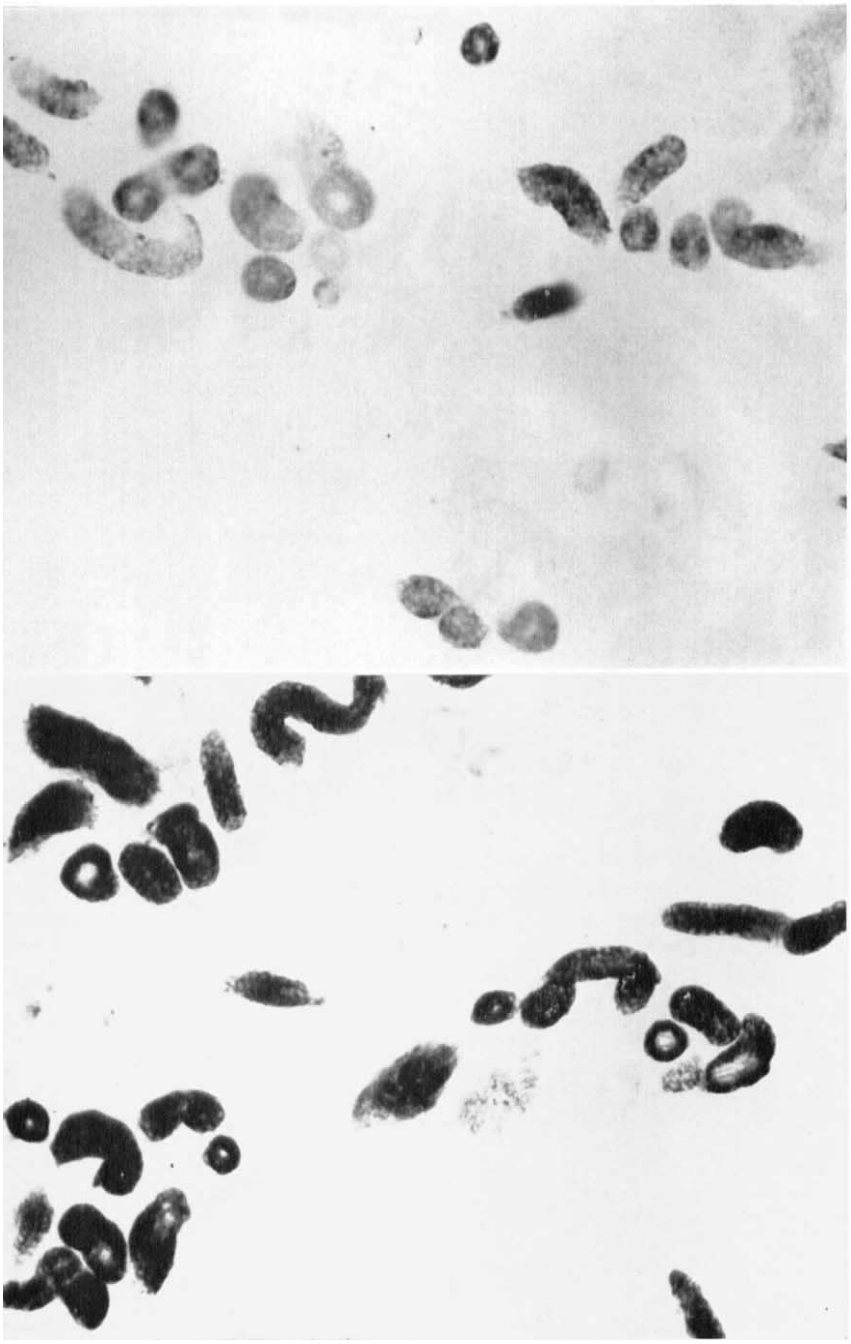

FIG. 3. Sweat glands before sweating. Weak to moderate phosphorylase a activity. (Godlewski technique—× 100).

FIG. 4. Sweat glands after 15 min. of sweating. Strong phosphorylase a activity. (Godlewski technic—× 100).

consistent difference between specimens obtained from areas injected with mecholyl and those which served as controls.

After sweating, there was a marked increase in phosphorylase *a* activity in the secretory coil in five animals. In the other two so studied, in which atropine was not used as an inhibitor in the control areas, there was equal activity in the secretory coils of both the mecholyl-injected and the control specimens. Phosphorylase *a* activity was always present in the duct, but this was unaffected by sweating.

In contrast to the changes produced in phosphorylase *a* activity, sweating had no effect on total phosphorylase.

DISCUSSION

These results indicate that glycogen can be depleted from the secretory cells of the palmar sweat glands of the rhesus monkey with a cholinergic drug, mecholyl. However, in order to demonstrate this response clearly, it is necessary to inhibit control areas with atropine since uninhibited control areas still show some secretory activity despite treatment of the animals with tranquilizers. This is in contrast to results obtained in the green monkey (*Cercopithecus aethiops*) (10) in which palmar sweating is inhibited by large doses of Sernyl. Our studies also demonstrate a constant level of total phosphorylase within the secretory cells, but an increase in phosphorylase *a* activity as a result of sweating. These findings suggest that phosphorylase *b* serves as a reserve from which phosphorylase *a* can be rapidly formed, and provides a mechanism by which a utilizable energy source can be rapidly derived from glycogen. The demonstration of phosphorylase *b* in the eccrine gland before sweating indicates that sweat gland phosphorylase is of the non-hepatic type, since hepatic phosphorylase is only slightly activated by AMP (11, 12).

SUMMARY

The secretory cells of the palmar sweat glands of the rhesus monkey deplete their glycogen after sweating is stimulated pharmacologically with mecholyl. This response is accompanied by an increase in phosphorylase *a* but no change in total phosphorylase. Our results suggest that phosphorylase *b* serves as a reserve from which phosphorylase *a* can be rapidly formed to break down glycogen to provide energy for secretory activity.

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